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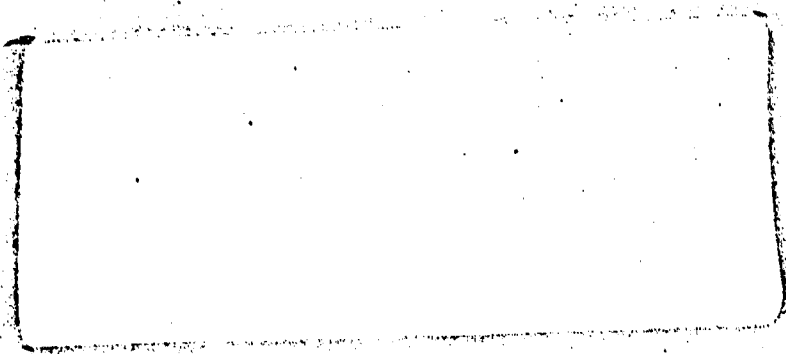### FOR
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(6) BLAST PRESSURE EFFECT ON PARACHUTE
DURING PAD ABORT FROM GEMINI/MOL.

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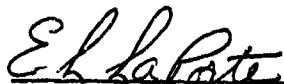AEROSPACE CORPORATION   400 156
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BLAST PRESSURE EFFECT ON PARACHUTE
DURING PAD ABORT FROM GEMINI/MOL

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technical applicability.

ABSTRACT

The effect of blast overpressure on a personnel parachute during pad-abort from a Gemini/MOL and subsequent booster explosion is presented in this report. For the representative case considered, that of a parachute 587 feet from a blast equivalent to 6800 pounds of TNT, the parachute only deflects 0.75 feet. This small deflection will not result in any parachute damage.

A

1.0 SUMMARY

An analysis was conducted to determine the potential crew hazard in the
event of a pad abort from a Gemini B/MOL/Titan-III and a subsequent
booster explosion. Specifically, the effect of the blast overpressure on
the C-9 canopy, suspending the astronaut, was investigated. The condition
selected for this analysis can be described as follows: the parachute deploys
3.5 seconds after jettisoning of the astronaut ejection seat, placing the
parachute deployment at a slant distance of 587 feet from the pad. At this
point, the shock wave passes the parachute, striking the top surface first.
The shock wave is produced by the detonation of 6800 pounds of TNT on the
pad (representative of Titan-III on-pad explosion).

The analysis presented herein indicates that the blast overpressure will
result in a localized parachute deflection of 0.75 foot, for the deployment
condition and explosion magnitude considered. This small deflection will
not result in collapse of the parachute, but only momentary load relief.

As the potential magnitude of the Titan-III explosion is not well defined at
the present time, and the parachute deployment conditions may vary from
the representative case considered, a summary of parachute displacements
versus explosion yields and representative distances from the explosion center
is presented in Figure 1. These results indicate that parachute collapse,
and entanglement, is a distinct possibility for reasonable equivalent
explosive yields and representative distances.

2.0 INTRODUCTION

An on-pad crew escape technique under consideration for the Gemini B/MOL/
Titan-III consists of ejection seats for removing the astronauts from the
Gemini B and parachutes for safely decelerating the astronauts to the ground.

In the :ve of : ooster explosion .fter ejection of the astronauts and
inflat n of thei parachut , a qu ion arises as to the effect of the
expl on created blast o pre ,e on the inflated parachutes. An
anal is has been con .vestigate the nature and extent of this
effect. The blast overpressure is considered to strike the top surface of
the parachute first, tending to collapse the chute, as this is believed to
be the most likely direction of the blast wave. The effect of a blast wave
direction into the underside of the parachute, although not considered in
this analysis, could result in excessive parachute loading and possible
failure. The effect of thermal radiation on the parachute (from the explosion
fireball) is not considered herein, although this may be much more
severe than the blast overpressure effect.

For this analysis, the following assumptions have been made:

a. The launch vehicle is still in launch position when the ejection seat
is initiated.

b. The trajectory of the ejection seat is normal, permitting the deploy-
ment of the parachute 3.5 seconds after the seat leaves the rail.

c. The blast will occur at ~uch a time after the evacuation of the astro-
naut, that the shock wave will impinge on the parachute canopy
immediately after it has fully opened. The slant range at this point
is 587 feet.

3.0 PARACHUTE PANEL DEFLECTION DUE TO BLAST OVERPRESSURE

The calculation of the blast wave characteristics and the resulting para-
chute deflection are discussed in detail in Appendix A. Only the general
approach to the problem and the pertinent results are discussed here.

The representative case studied is that of a parachute moving at a velocity
of 120 feet per second at a slant range of 587 feet from a blast equivalent
to 6800 pounds of TNT. This corresponds approximately to the point where
the parachute has just deployed under normal operation. The analytic model
used to calculate the parachute panel deflection assumes that the panel would
move at the same speed as the air particles behind the shock. This model
is reasonable because the parachute panel is very light and free to deflect
in the direction of positive overpressure. The local deflection resulting from
this model is 0.75 foot at the impact center for the representative case.
Conditions other than the representative case have also been considered and
the results are given in Figure 1 (Appendix A).

4.0   DISCUSSION

For the representative case considered, a local panel deflection of 0.75 foot
will not result in collapse or damage to the parachute. If, however, the
blast equivalent were greater than assumed, or the separation distance
were shorter, Figure 1 shows that a potential parachute collapse problem
could exist. It is considered that deflections greater than 6 feet for a C-9
canopy could result in parachute collapse. If the parachute does collapse,
then entanglement could occur and prohibit the parachute from re-inflating
after the disturbance has passed.

The analysis presented herein is theoretical, and not substantiated by test
results. In an effort to obtain test verification, an intensive search of
available literature was conducted, as well as inquiries at Norton Air Force
Base, the Naval Air Facility at El Centro and at the Flight Dynamics
Laboratory at Wright-Patterson Air Force Base. No pertinent data was
obtained that could provide positive verification, or negate the results
of this analysis. The consensus of informed personnel contacted however,

was that a high probability of parachute collapse existed. To provide
verification of the theoretical model utilized, in the light of the existing
"intuitive" contrary opinion, it is recommended that free flight testing
be conducted to support or refute this analysis. These tests may also
serve to indicate possible corrective actions that may be taken, if a problem
is shown to exist.

APPENDIX A

CALCULATION OF BLAST WAVE OVERPRESSURES
AND PARACHUTE DEFLECTIONS

1.0 Shock Characteristics (Air)

In investigating the effect of explosive-generated shocks on structures, the following shock characteristics or parameters are of interest:

P = shock overpressure (above ambient)

q = dynamic pressure of air behind shock

M_x = shock Mach number

t = time after arrival of shock

t_d = time duration of positive overpressure

α = decay parameter of positive overpressure

U_p = particle velocity behind shock

If any one of these parameters is known, the others can be found by use of equations or tables in Reference 1.   In general, the overpressure (P) is found through the application of scaling laws (see below) and is used as the table entry for other parameters.   The overpressure and the dynamic pressure decay with time after passage of the shock according to the following empirical equations:

$$P/P_{max} = (1 - t/t_d) \exp(-\alpha t/t_d) \qquad (1)$$

$$q/q_{max} \doteq (1 - t/t_d)^2 \exp(-2t/t_d) \qquad (2)$$

2.0 Scaling Laws

Generally, graphs or tables of shock overpressure and time duration as functions of distance from the explosion can be found for a reference

equivalent TNT yield (one ton in Reference 1, and one kiloton in Reference 2). These parameters can be determined for any other desired yield through the application of scaling laws. These relations at one atmosphere are:

$$\text{Actual distance} \quad = \quad \text{scaled distance } (W/W_o)^{1/3}$$

$$\text{Actual time} \quad = \quad \text{scaled time } (W/W_o)^{1/3}$$

3.0 Analytic Model

Consider one unit area at the center of the parachute canopy. When the blast wave first hits the parachute from above, the wave will be reflected as if the parachute panel were a rigid surface. The maximum overpressure P_{max} can be calculated accordingly. If the parachute panel were indeed rigid and cannot deflect, the overpressure would decay according to Equation (1). However, the initial overpressure (that is P_{max}) immediately sets the parachute panel in motion which causes the wave to reflect at a lower strength than in the rigid surface case. As a result, the movement of the parachute panel attenuates the overpressure as time goes on and the overpressure decays at a faster rate than Equation (1) shows.

Preliminary wave diagram calculations conducted by Dr. R. D. Long of the Aerophysics Section indicated that an unrestricted (free to move) parachute panel would pick up speed and attenuate the overpressure very rapidly. In a period of a fraction of a millisecond, the parachute panel speed approaches the particle speed behind the shock since the parachute is very light. It weighs 0.00763 pound per square foot while the air density at sea-level is 0.076 pound per cubic foot. Thus, the parachute panel corresponds in weight to about 0.1 foot thick air layer. Since the parachute panel thickness is negligible and a tenth of a foot is very small compared with the characteristic dimension of the problem, one can treat the parachute panel as an imaginary interface of approximately the same density as air. This being the case, one can simply assume that the parachute panel will move at the same speed as the air particles behind the shock. This is the basic analytic model to be used in the following calculations.

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4.0 Calculations

4.1 Scaling - Shock Properties

The following given conditions are assumed for the representative case.

Equivalent yield	=	6800 pounds of TNT
Parachute range	=	430 feet
Parachute height	=	400 feet
Slant range	=	587 feet (corresponds to distance away from the blast center)
Parachute speed	=	120 feet per second

For a reference yield of one ton (Reference 1), the scale factor is:

$$(W/W_o)^{1/3} = 1.5$$

and the scaled distance = 587/1.5 = 391 feet. By extrapolation of the data in Reference 1, we find the following pertinent shock properties:

Maximum overpressure, P_{max} = 1.0 psi

Shock Mach No., M_x = 1.029

Maximum particle velocity behind shock, $U_{P_{max}}$ = 53 feet/second

Time duration of positive overpressure, t_d = 0.04 second

4.2 Assumptions and Simplifications

Before using the shock data for the parachute problem, certain simplifications and assumptions are required. These are discussed here, not necessarily in the order of importance.

(1) The parachute moves at 120 feet per second. This creates a differential pressure of approximately 0.1 psi across the parachute panel. The effect of this small differential pressure is neglected in computing the parachute displacement.

(2)   The air in the wake of the parachute is assumed to have a negligible velocity relative to the parachute panel. Essentially these two (1 and 2) assumptions simplify the analytic model to a moving spherical shock striking a stationary interface in a 14.7 psi atmosphere.

(3)   From the dynamic pressure Equation (2), one obtains

$$U_p = \sqrt{\frac{\rho_{Max}}{\rho}}\ U_{p_{max}}\ (1 - \frac{t}{t_d})\ \exp(-t/t_d) \tag{3}$$

For weak shocks (overpressure of the order of a few psi), the square root of density ratio in Equation (3) is approximately unity. For example, for a 5 psi overpressure, the maximum value of the density effect is

$$\sqrt{\frac{\rho_{max}}{\rho_{amb}}} = \sqrt{\frac{5 + 14.7}{14.7}} = 1.16$$

The average effect should be smaller than this. It is assumed in the present analysis that the density effect is negligible.

(4)   Computed below is the deflection of the parachute during the period of positive overpressure only. The time duration of positive overpressure and the time duration of positive dynamic pressure are slightly different from each other. The former is shorter than the latter. However, the difference for weak shocks is low and it can be disregarded. Thus, the positive particle velocity phase is assumed to extend to the same time as the positive overpressure, i.e., the values of t_d in Equations (1) and (2) are assumed equal.

4.3   Parachute Displacement

Based on the assumptions and simplifications discussed, the parachute displacement is obtained by integrating U_p from $t = 0$ to $t = t_d$. This results in the following displacement:

$$\text{Displacement} = \frac{U_{p_{max}} t_d}{e} \tag{4}$$

For the representative case, the displacement is 0.75 foot. This shows that
the parachute panel at the center of the canopy would deflect approximately
one foot. An early investigation (Reference 3) showed that it would deflect
approximately 9 feet. The analysis presented in Reference 3 was understood
to be conservative in the sense that it predicted the largest deflection. The
analytic model used in that analysis was to treat the parachute panel as a rigid
surface, thus the blast wave reflects from the surface in its full strength during
the entire period when the panel is in the pressure field of the blast wave. The
effect of the deflection of the parachute panel (due to the blast pressure loading)
on the wave reflection strength was not taken into account. It is felt that the
result of Reference 3 is probably overly conservative.

Conditions other than the representative case were also considered. The results
are given in Figure 1, which is a plot of the displacement during the positive
overpressure phase as a function of the actual distance away from the center of
explosion for four different equivalent yields. The corresponding maximum
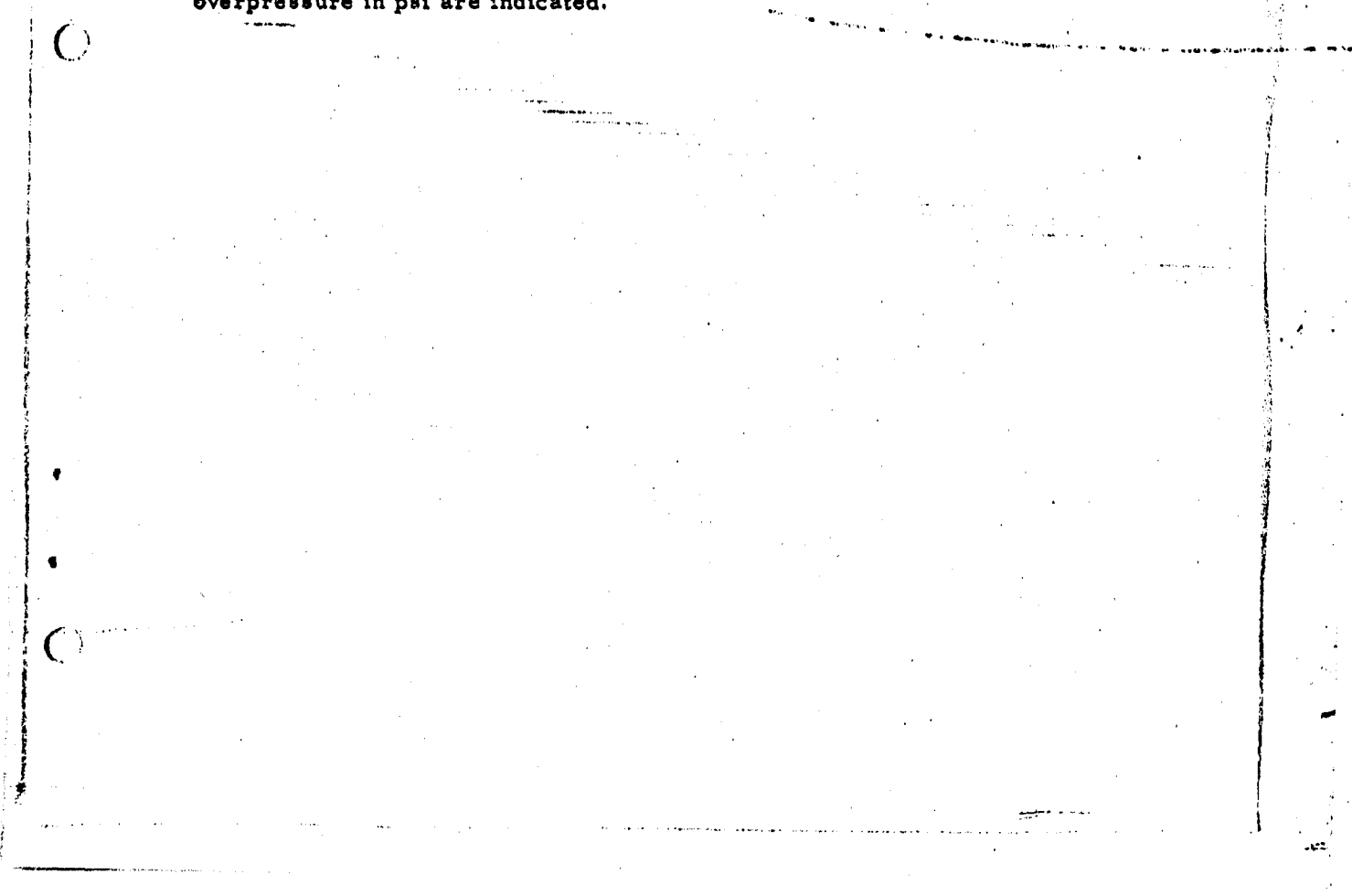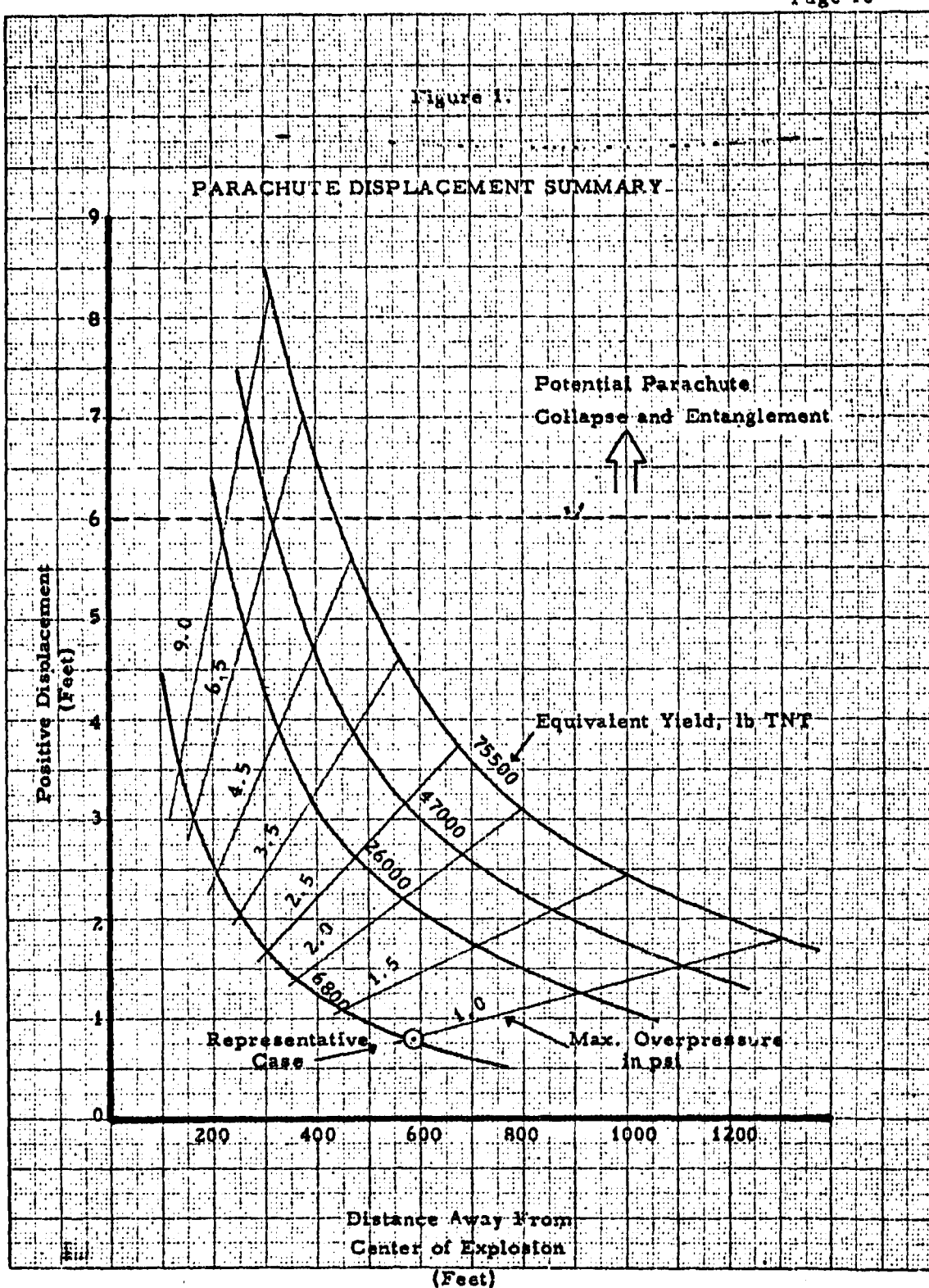overpressure in psi are indicated.

Figure 1.

PARACHUTE DISPLACEMENT SUMMARY

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2. The Effects of Nuclear Weapons, Samuel Glasstone, ed., United States Department of Defense, 1962.

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